

# An overview of different tools for smart grid studies

Experiences from several European projects

Serdar Kadam

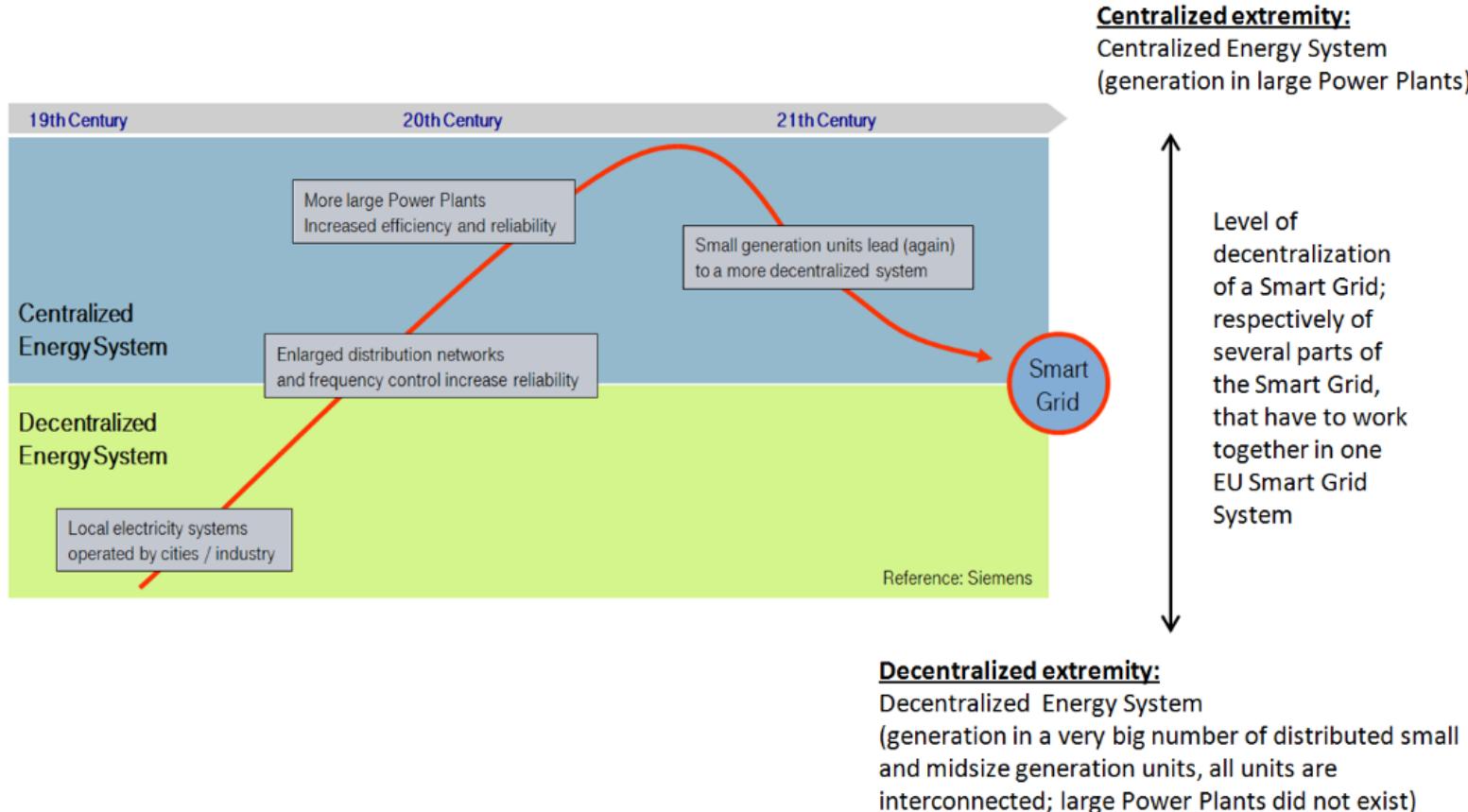
# Outline

- Introduction
- Tools and methods in research projects
- Synthetic networks and probabilistic tools
- Large-scale network data analysis
- Conclusion

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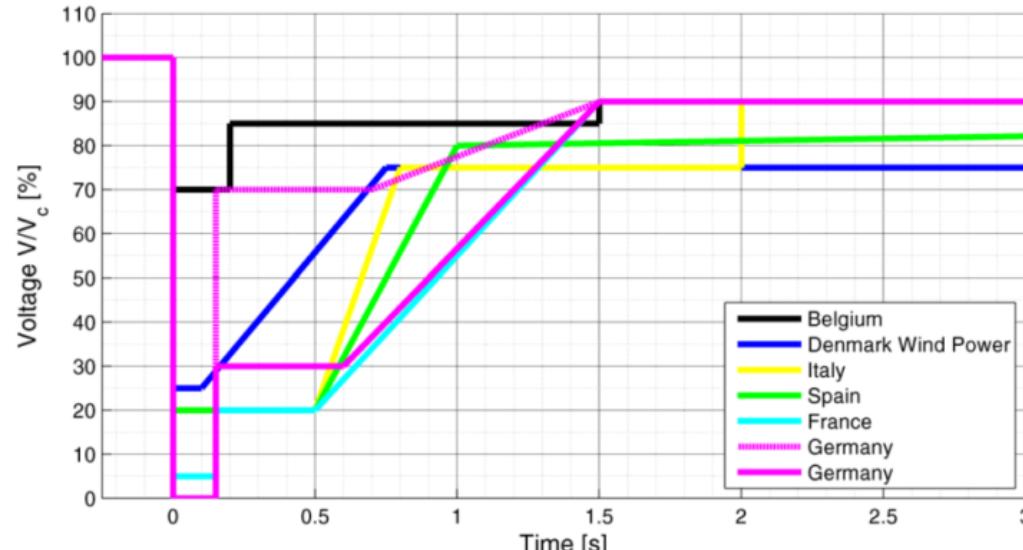
# Centralized and Decentralized Energy System



# Growing need for network support from DER

## Distributed Energy Resources and LVRT

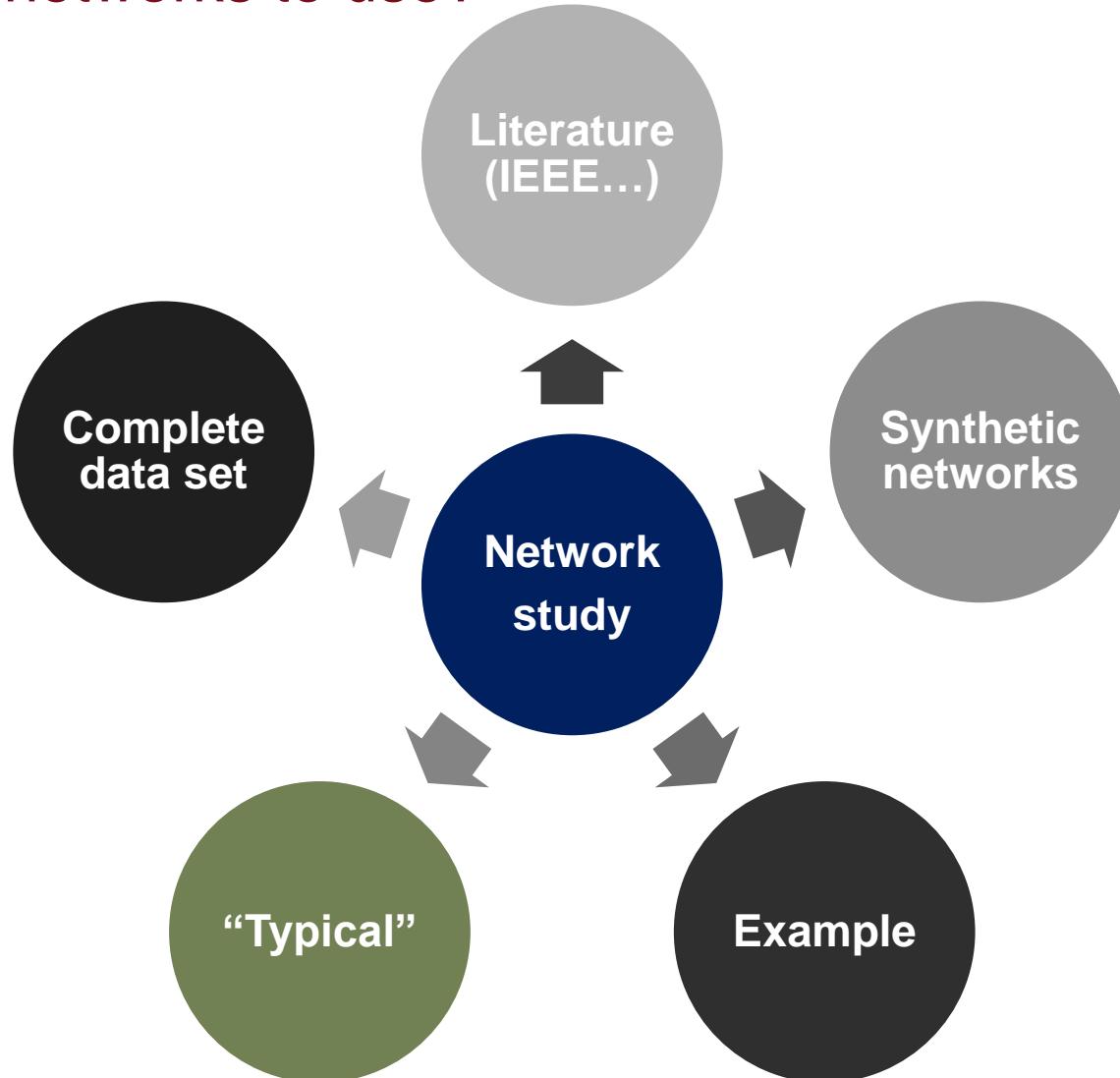
- E.g. Germany: BDEW Guideline “Generating Plants Connected to the Medium-Voltage Networks”
- Key documents FGW TR3 (Measurement), TR4 (Model validation) TR8 (Certification procedure)
- Test specification IEC 61400-21 Measurement and assessment of power quality characteristics of grid connected wind turbines SDLWindV Additional requirements and amendments



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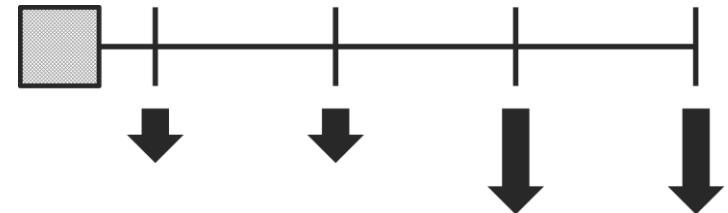
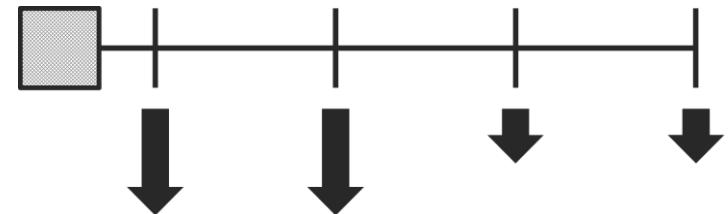
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## Q1: Which networks to use?



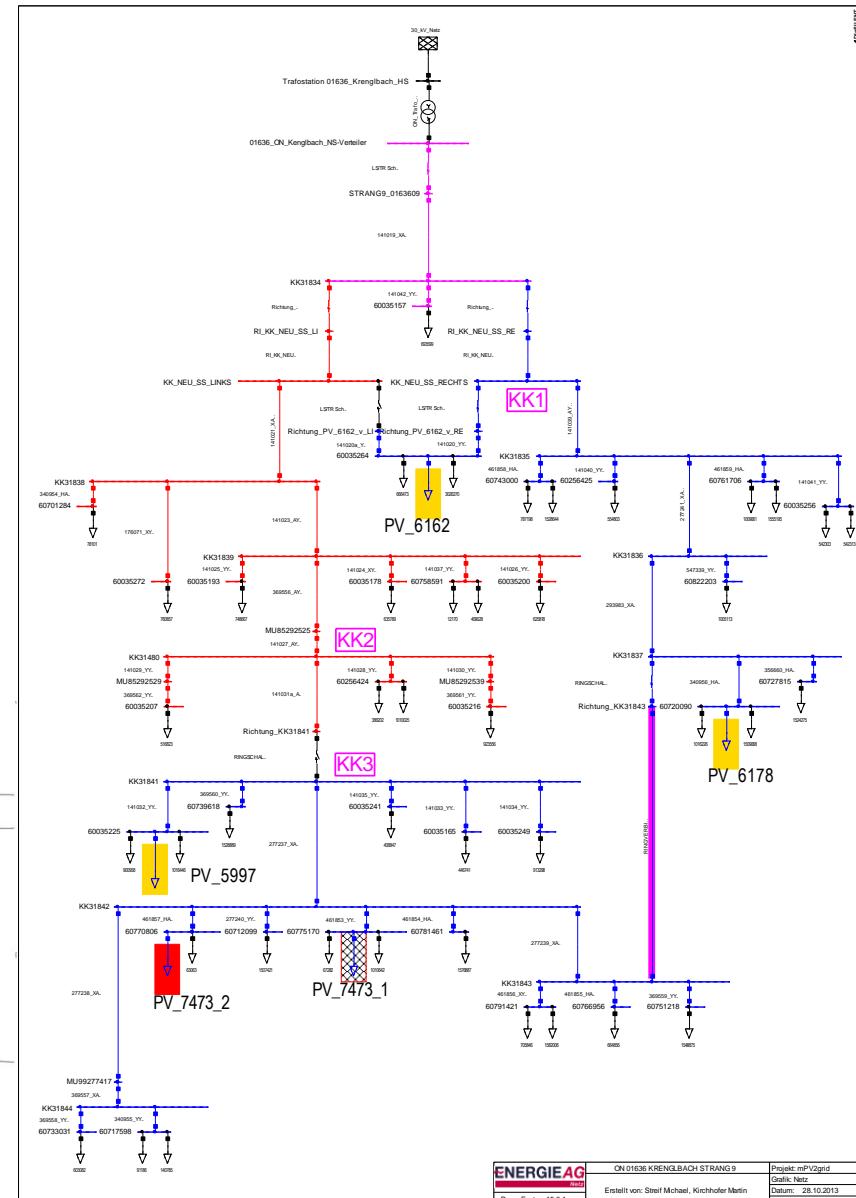
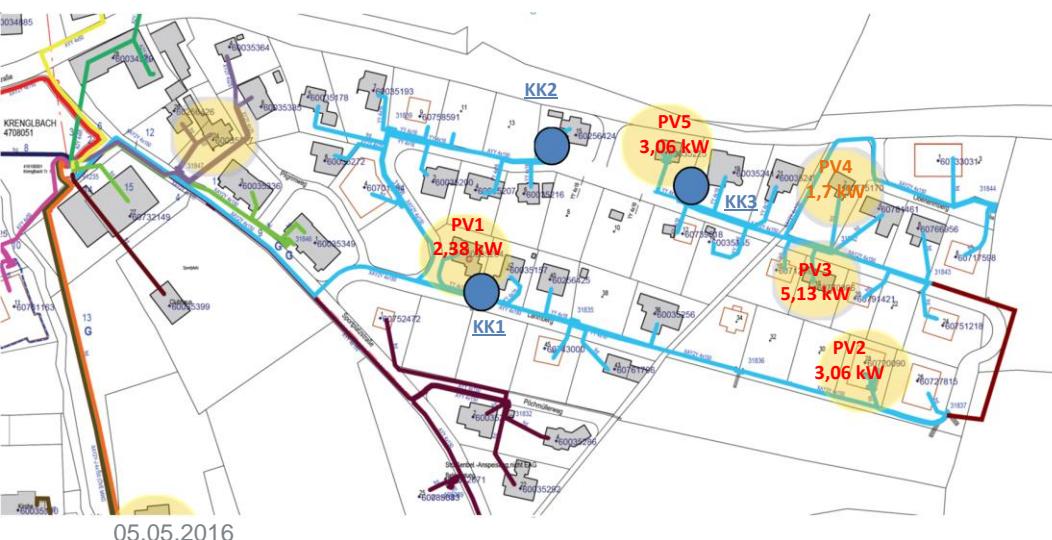
## Q2: Which DRES scenario to consider?

- Generation at the beginning:  
(high HC)
- Generation at the end:  
(low HC)



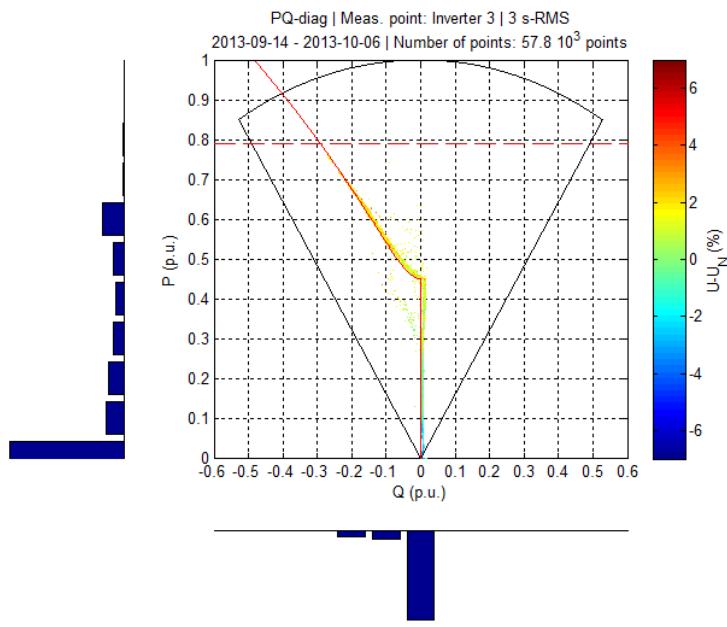
# morePV2grid – local voltage control through PV inverters

- >800m LV-feeder
- 5 single-phase installations, 4 controllable (15kWp) on same line
- Simulation, Lab tests, Field tests
- 2010-2013

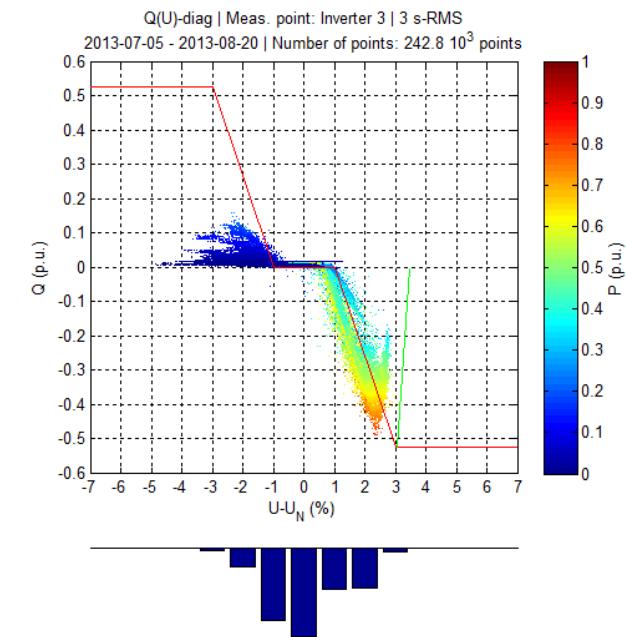


# Functional validation in the field

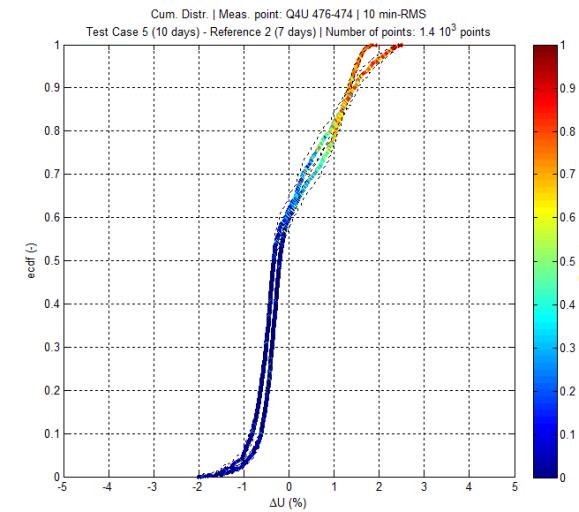
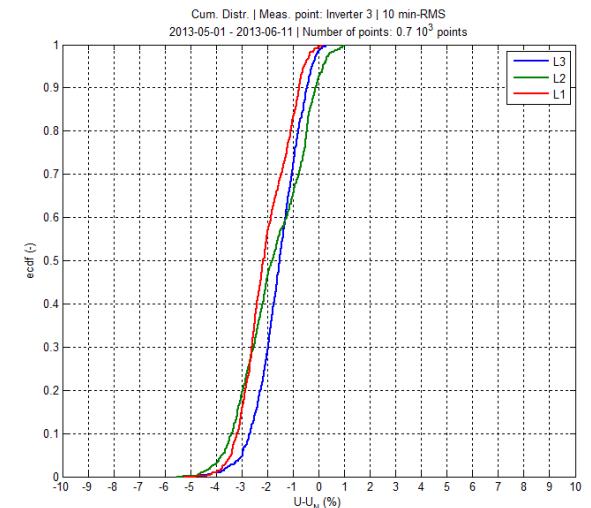
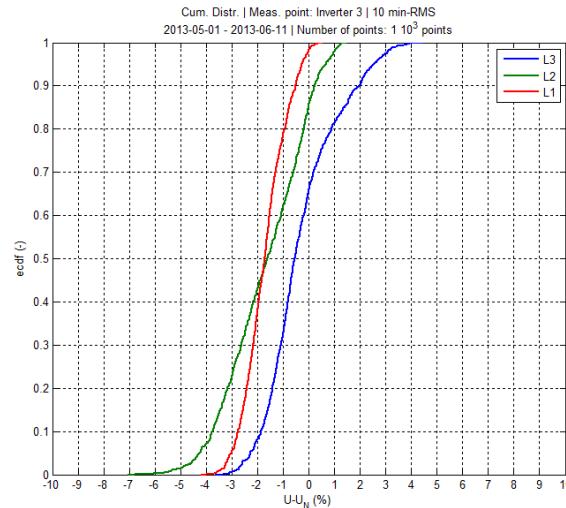
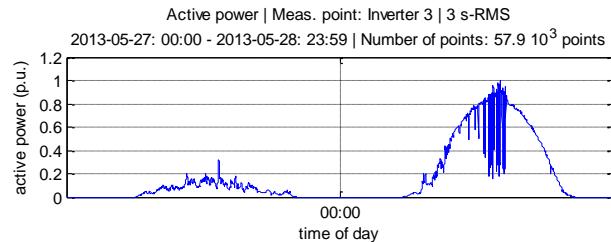
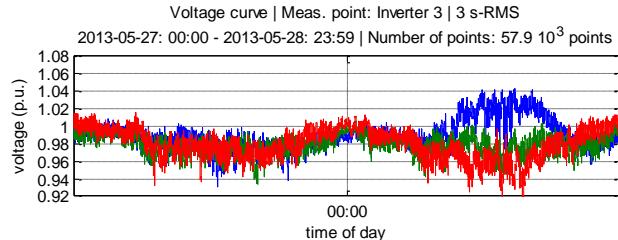
$\text{Cos}\varphi(P)$



Q&P(U)-control



# Assessment of smart grid schemes



# MetaPV in a Nutshell – Large scale demonstration of network support through PV inverters

[www.metaPV.eu](http://www.metaPV.eu)

- October 2009 - March 2015
- Budget:
  - € 5.5 million funding from the EC € 9.5 million total eligible budget
- Partners : 3E, AIT, Infrax, LRM, SMA, UoL
- Large scale demonstration
  - Residential : 85 installations, ~400 kW
  - Industrial (MV): 9 installations, ~2500 kW
- Approach:
  - Development and simulations
  - Lab tests
  - Field tests and validation



© mediagram

# Challenges of demonstration projects (MetaPV experience)

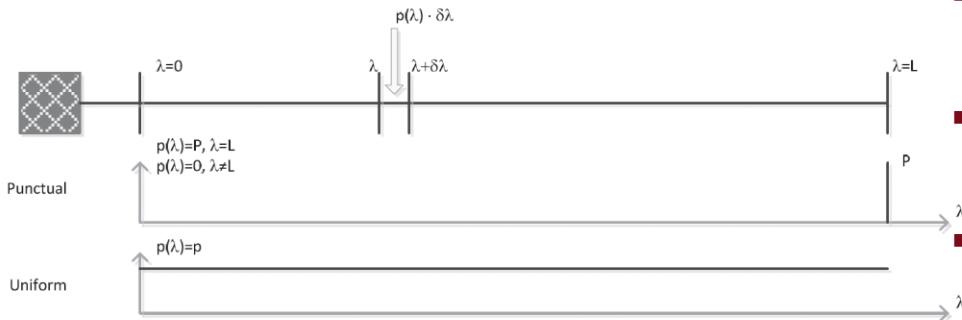
- **Results very positive:**
  - no equipment failure, no malfunction.
  - functionality demonstrated: control behaves as intended!
- **Demo projects** as a key step towards the large-scale deployment (**functional validation**)
- What a demo can do:
  - Foster a better understanding from all parties (DSO, equipment manufacturer, R&D)
  - **Demonstrate the functionality**
- What a demo usually does not do:
  - Study the potential for **scalability** and **replicability** (beyond the particular conditions of the demo)
  - Provide guidance on **how to replicate** the solution
  - Provide “general results”



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# Generic Feeder study

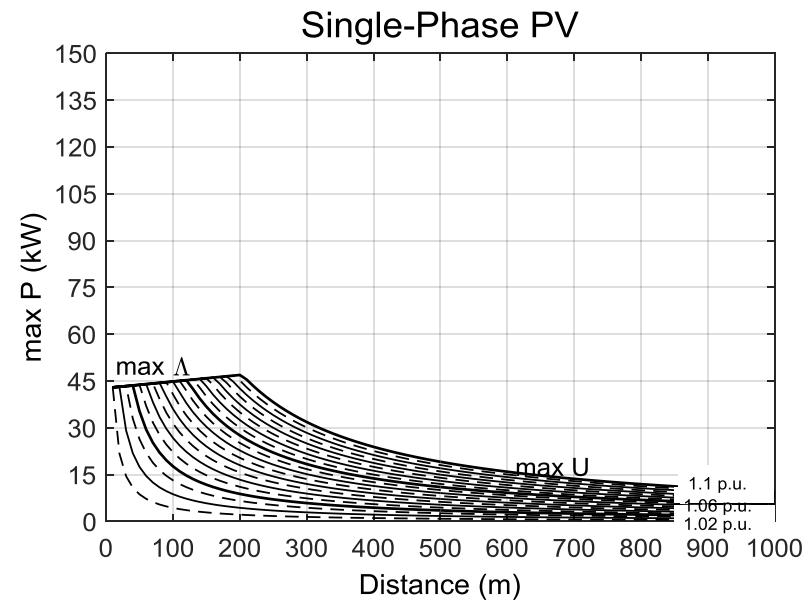
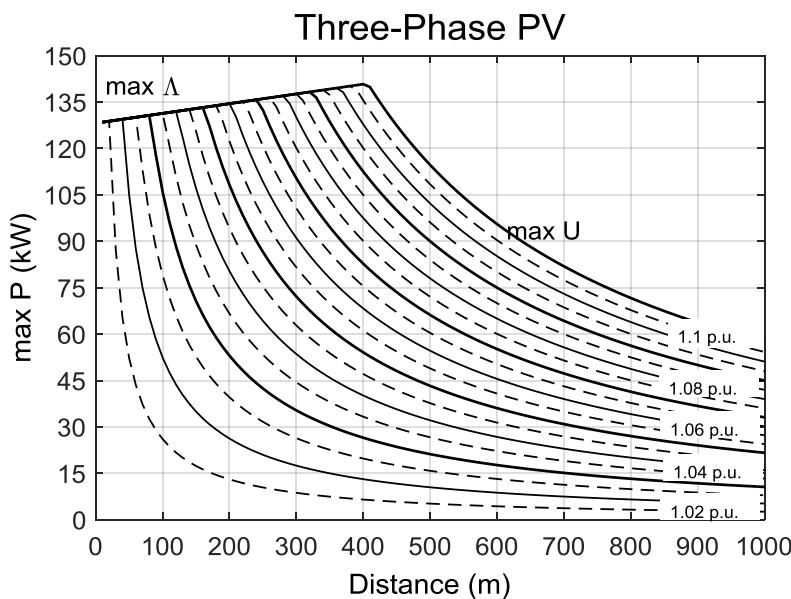
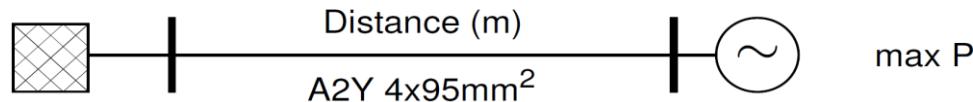


- Continuous feeder with slack
- Punctual or continuous load (100 loads)
- Balanced and unbalanced load flow
- Type of cable / length
- Allowed voltage rise:
  - Currently: 3 % (AT, DE)
  - Sensitivity study: 1-10 % (e.g. through distribution transformer with OLTC)

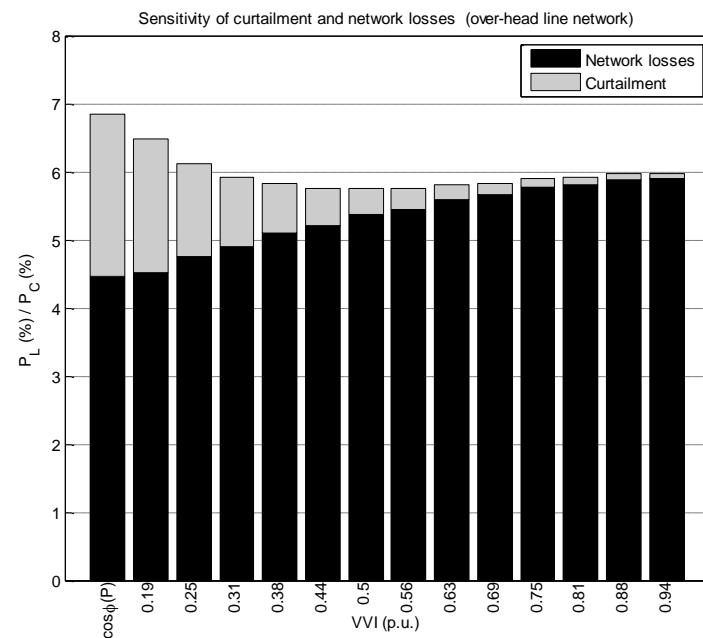
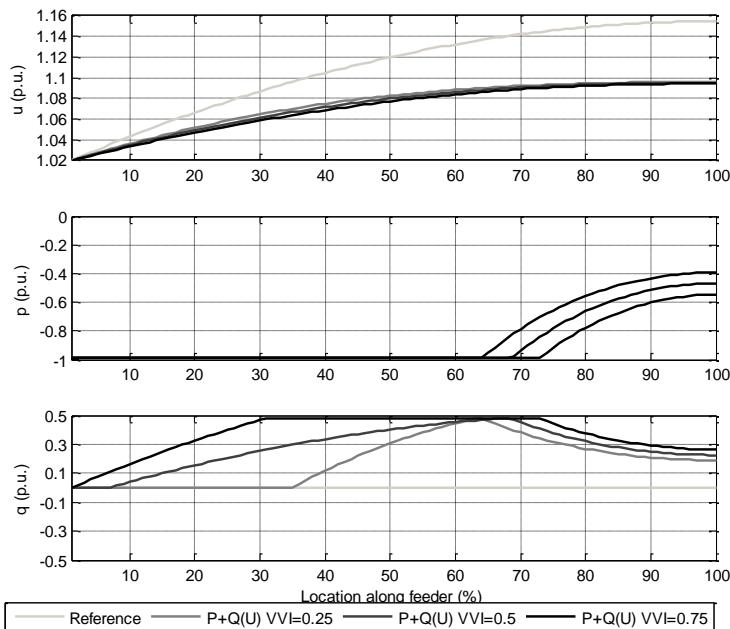
Cross-section (mm <sup>2</sup> )	Overhead Line (OL)	Cable (CBL)
<b>50</b>	OL_A1_4x50	CBL_4x50
<b>70</b>	OL_A1_4x70	CBL_4x70
<b>95</b>	OL_A1_4x95	CBL_4x95
<b>120</b>	OL_A1_4x120	CBL_4x120
<b>150</b>		CBL_4x150
<b>240</b>		CBL_4x240

# Hosting Capacity in LV network ( $U_N = 0.4\text{kV}$ )

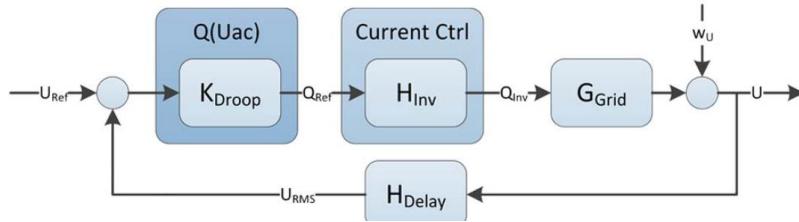
- Hosting Capacity study for typical cable
- No loads considered



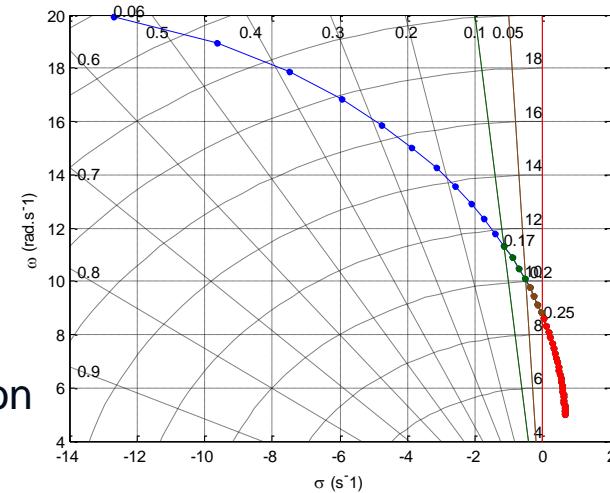
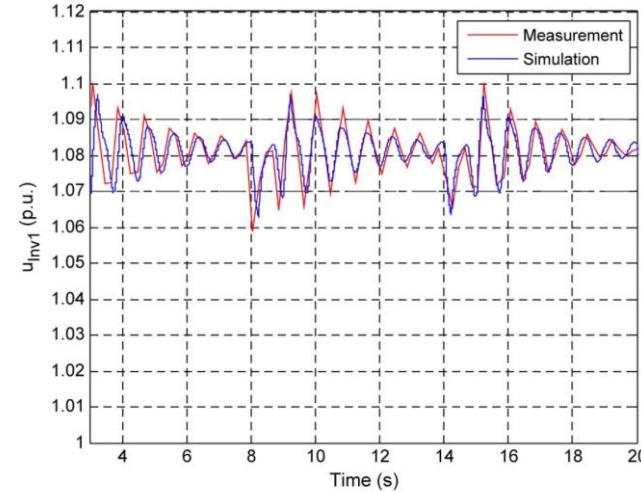
# Parametric Q&P(U)-study



# AIT study on the stability of Q(U)-control

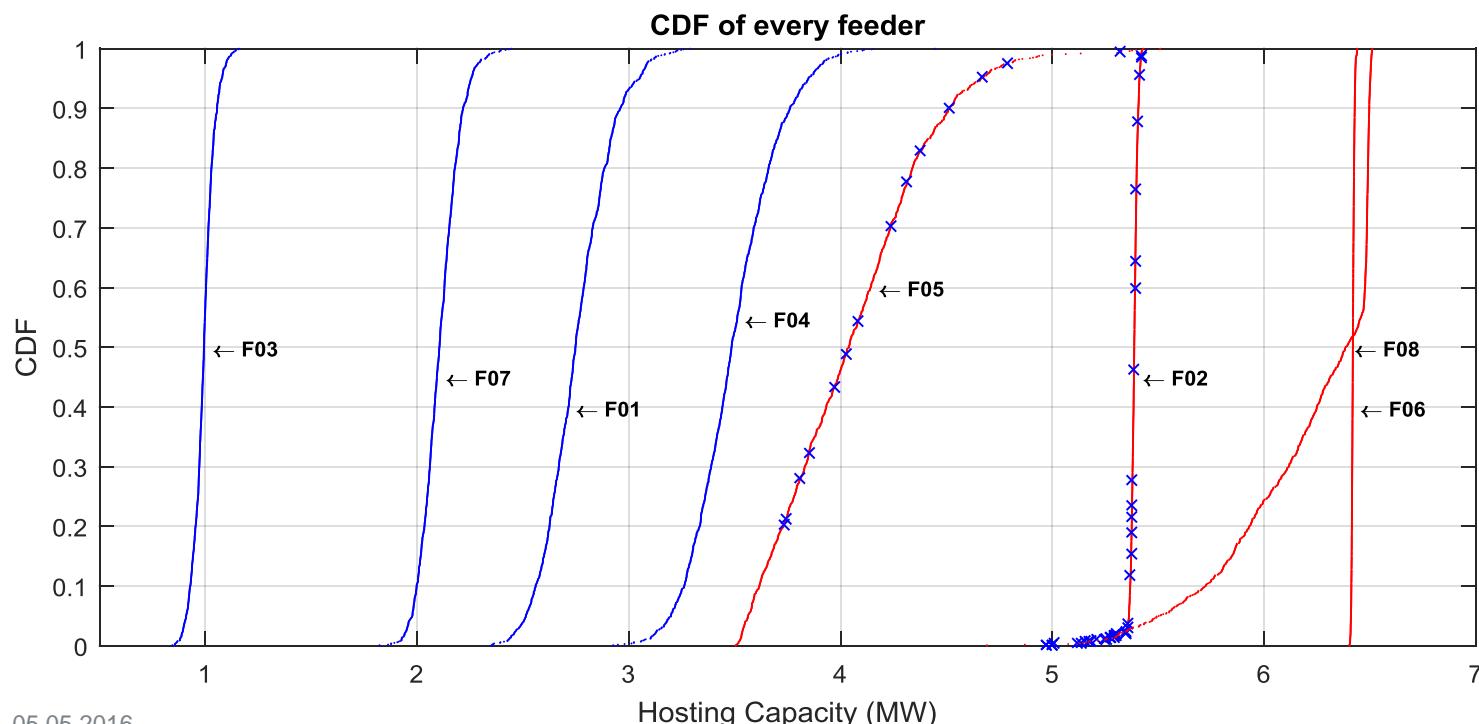


- Could several inverters with a Q(U)-control become instable?
- Stability criterion:  $\frac{T}{\tau} \leq \frac{1}{a_\zeta \cdot \frac{\Delta U_{PV}}{\Delta U_{droop}} \cdot \frac{\tan \varphi}{R/X} + b_\zeta}$
- Delay shall be lower than half of the desired response time
- → Relevant for systems relying on communication

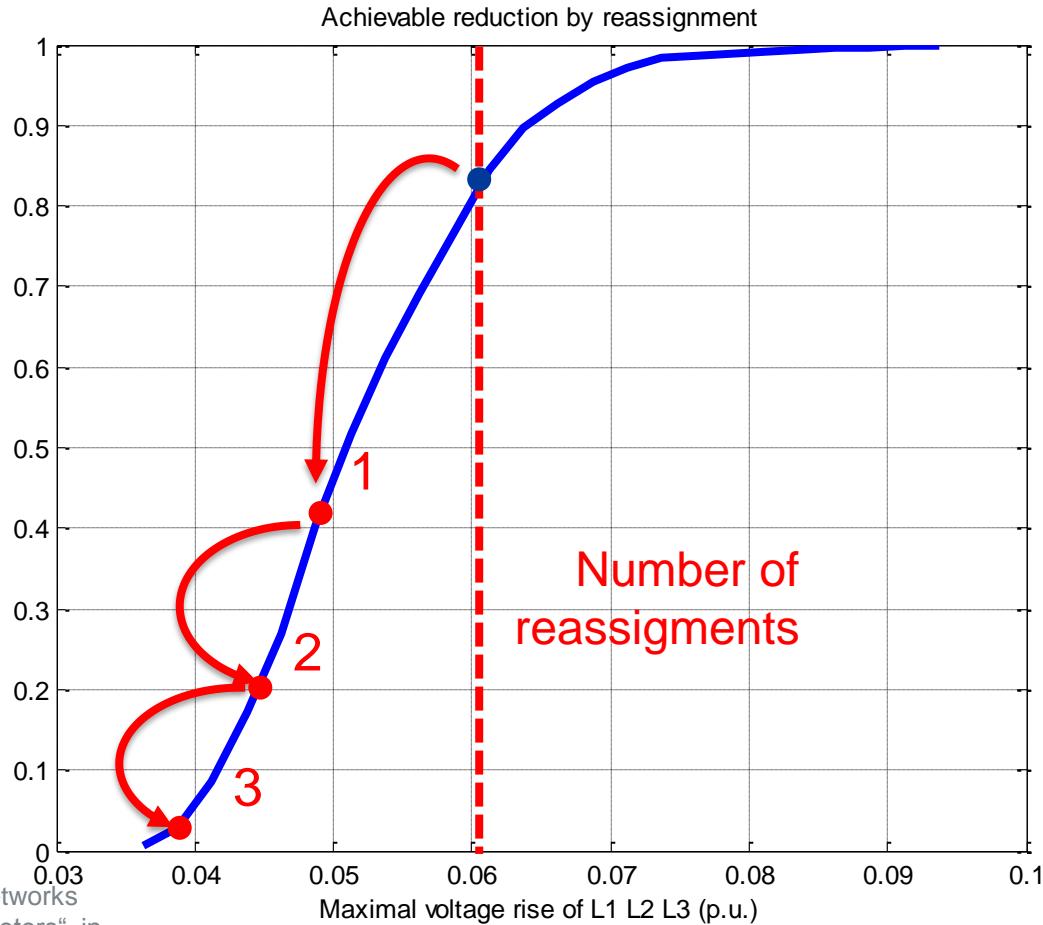
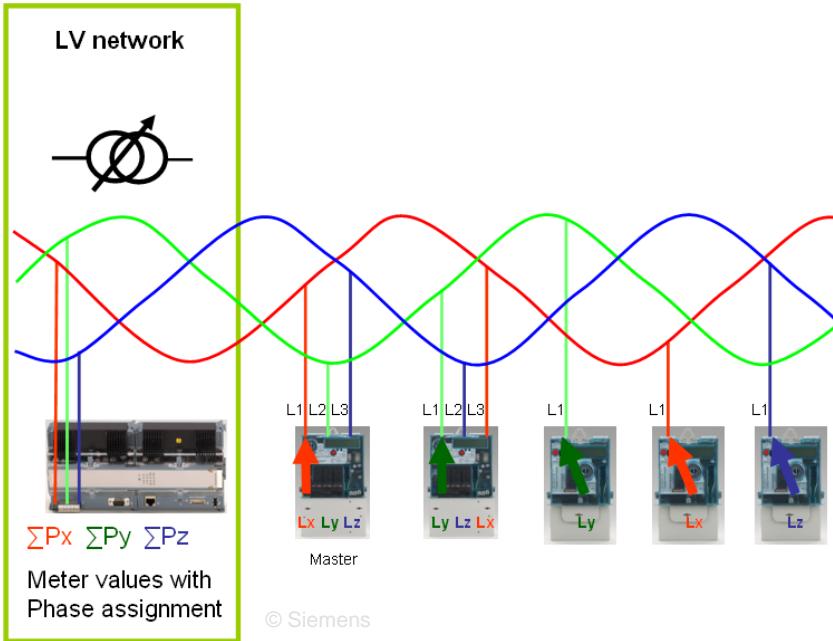


# Hosting Capacity Feeder Screening (MV network)

	F01	F02	F03	F04	F05	F06	F07	F08
<i>Length (km)</i>	11.9	6.2	38.5	14.2	4.6	5.8	15.1	10.5
<i>DER number</i>	24	18	87	43	8	19	50	24



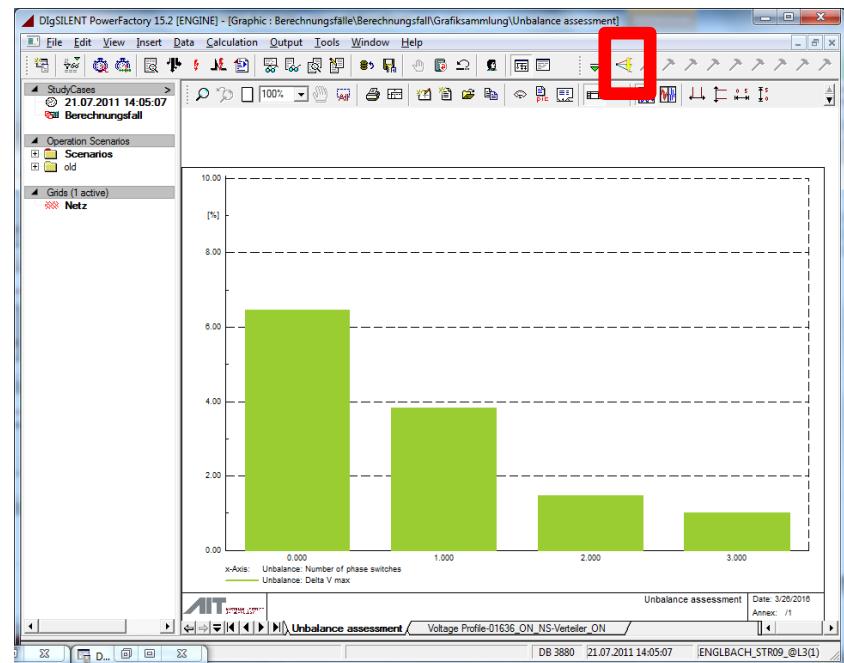
# Pareto optimal distribution of Single-phase DER



B. Bletterie, S. Kadam, R. Pitz, und A. Abart, „Optimisation of LV networks with high photovoltaic penetration—Balancing the grid with smart meters“, in Proc. PowerTech 2013 IEEE Grenoble, 2013, S. 1–6.

# Pareto-optimal reassignment of single phase installations

- Easy to use tool
- Network data from GIS  
(GIS-DGS - PowerFactory)
- PV/Load data from GIS and metering data-base (AMI-PowerFactory/Python)
- User-defined balancing tool
- Result: report & diagrams



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# IGREENGrid

## Challenge

- IGREENGrid project focuses on identifying the most promising solutions for increasing the hosting capacity for Distributed Renewable Energy Sources (DRES) in power distribution grids without compromising the reliability or jeopardizing the quality of supply.

## Set of guidelines:



Most promising solutions.



Recommendations for the **integration of DRES** in distribution grids, Methodologies and tools.



Criteria to establish **hosting capacity** and to manage **curtailment procedures**.



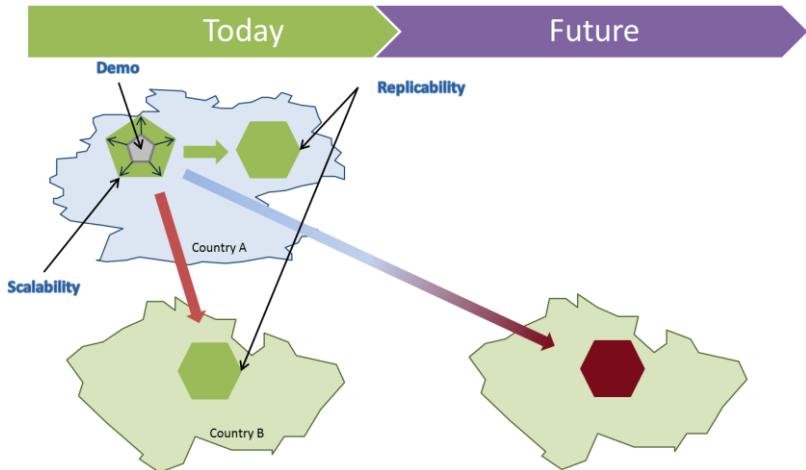
**Technical requirements** to DRES, equipment manufacturers & technology providers.



Assessment of the **scalability** and **replicability** at EU level (from technical, regulatory and economic point of view).

# iGreenGrid Key facts

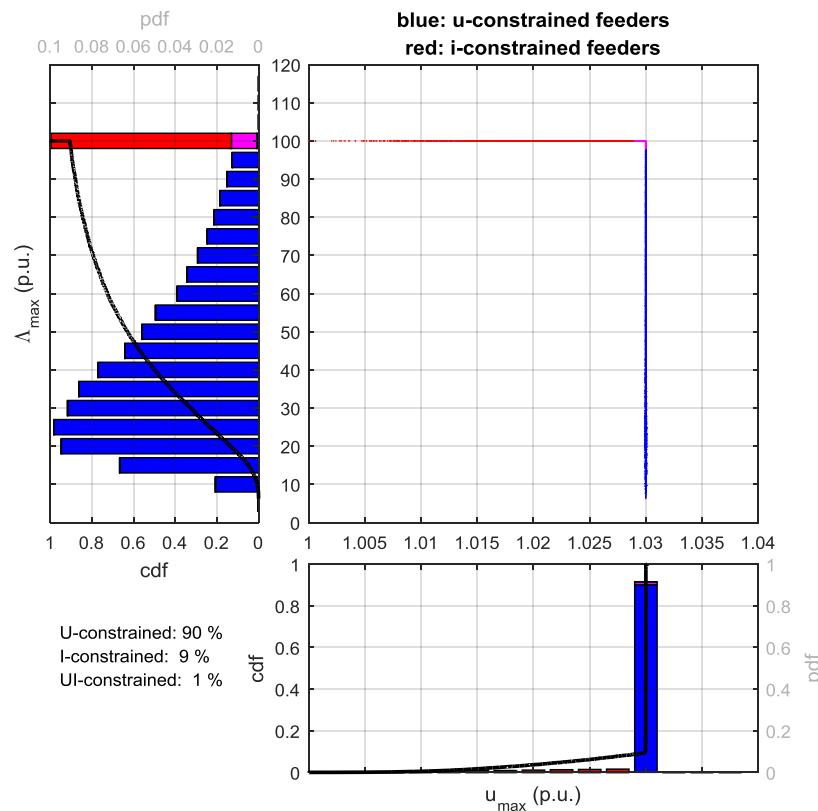
- > 15 smart grids solutions (MV&LV)
- Data:
  - Network data from GIS/NIS/SCADA
  - Load data (metering / SCADA)
  - PV (& Wind) data per country
- From 8 DSOs:
  - 149 MV feeders (27 networks)
  - 55 LV feeders (16 networks)
- From 2 DSOs:
  - >11.000 LV networks
  - >37.000 LV feeders



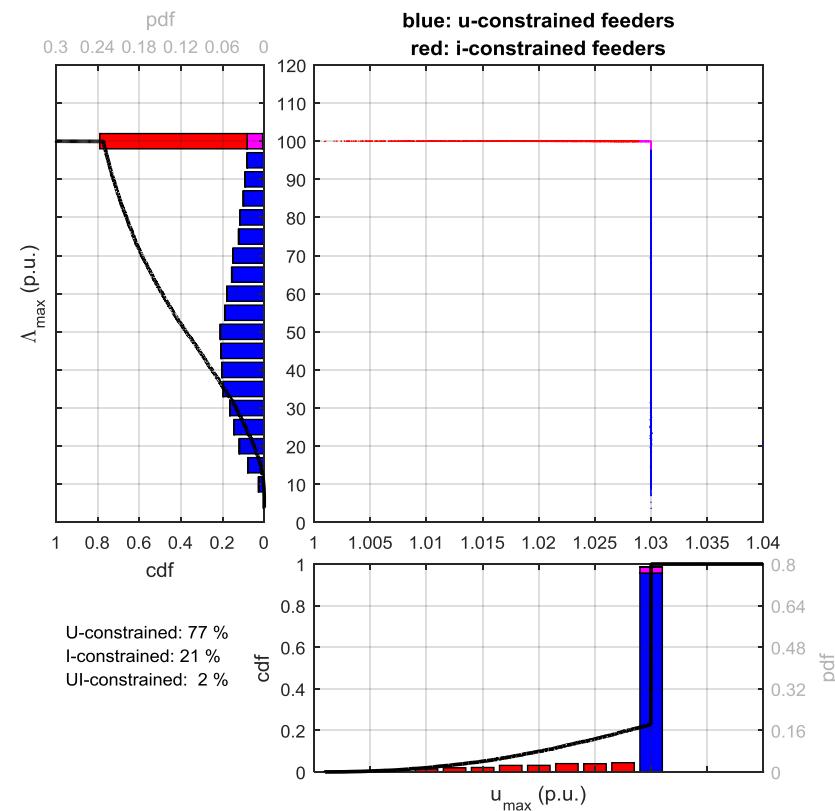
# Feeder characterization

(~11.000 LV networks and 37.000 LV feeders)

DSO1

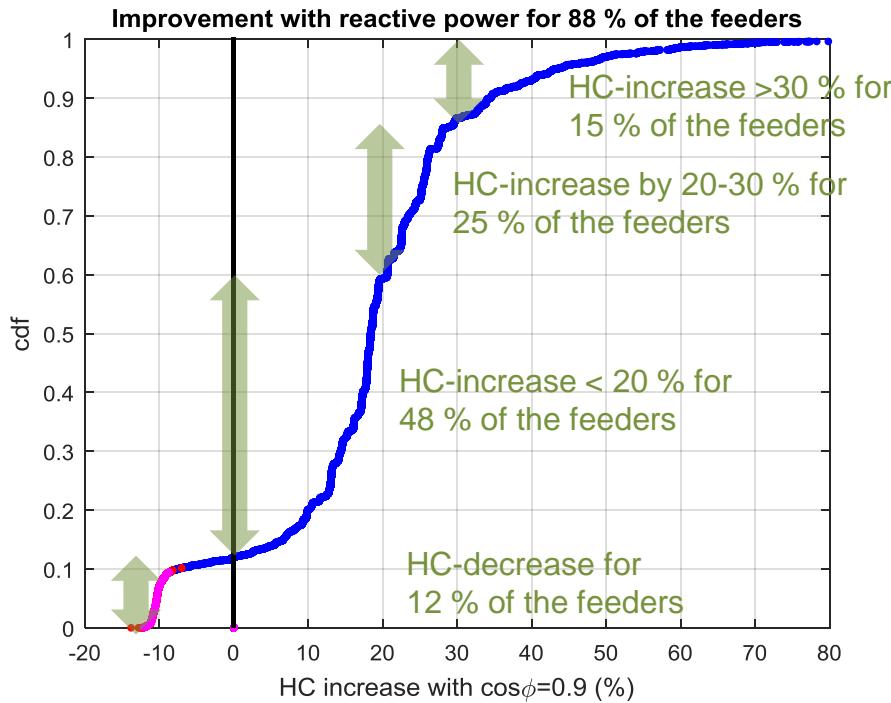


DSO2

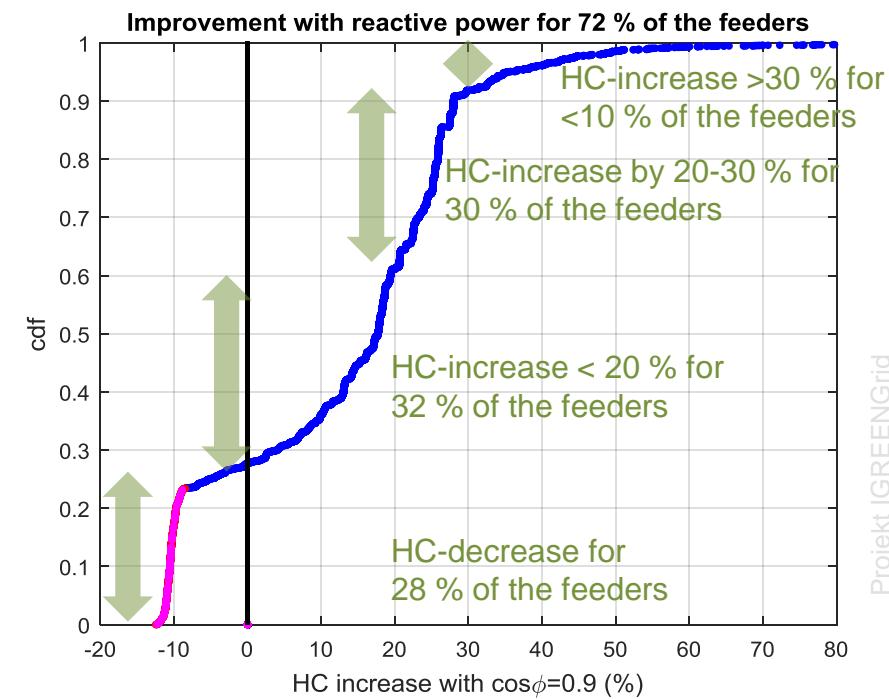


# Reactive Power and Hosting Capacity

DSO1 ~25.000 LV-feeders



DSO2 ~12.000 LV-feeders



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# Conclusion and Outlook

- Different tools for different tasks...
  - Simulations, laboratory and field tests
  - Load flow, Probabilistic LF, OPF, Quasi-Dynamic, RMS-simulations...
  - Proof of concept ( e.g. Q(U)-Stability)
  - Parametric studies (e.g. Q(U)-control)
  - Probabilistic assessment (e.g. HC-screening, Pareto-optimal switching)
  - Scalability & Replicability (Grid data needed)

# AIT Austrian Institute of Technology

your ingenious partner

Serdar Kadam

Energy Department  
Electric Energy Systems  
Gieffinggasse 2 | 1210 Vienna, Austria  
[serdar.kadam@ait.ac.at](mailto:serdar.kadam@ait.ac.at) | +43 664 8251298 | [www.ait.ac.at](http://www.ait.ac.at)